RESEARCH DEPARTMENT

Image orthicon investigations: a comparison between magnesium–oxide and glass targets for image orthicons

REPORT No. T·100/3

1963/19

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

IMAGE ORTHICON INVESTIGATIONS: A COMPARISON BETWEEN MAGNESIUM-OXIDE AND GLASS TARGETS FOR IMAGE ORTHICONS

Report No. T-100/3

(1963/19)

D. Maurice

S.M. Edwardson, A.M.I.E.E.

(D. Maurice)

Report No. T-100/3

IMAGE ORTHICON INVESTIGATIONS:
A COMPARISON BETWEEN MAGNESIUM-OXIDE AND GLASS TARGETS FOR IMAGE ORTHICONS

April 1963

Report No. T-100/3

(1963/19)

IMAGE ORTHICON INVESTIGATIONS:

A COMPARISON BETWEEN MAGNESIUM-OXIDE AND GLASS TARGETS FOR IMAGE ORTHICONS

SUMMARY

Measurements have been made to compare the performance of two 3 in image orthicon camera tubes which differed from each other only in respect of the material used for the target. It has been found that the tube having a magnesium-oxide target offers no advantage in sensitivity over the conventional glass-target tube although it possesses a number of desirable features not found in the latter.

1. INTRODUCTION

The image orthicon with the thin film, magnesium-oxide semiconductor target has been developed by the General Electric Company of America, for use at low illumination levels and with particular application to outside broadcasts in colour. This tube has been described elsewhere[1,2] and only the main advantages claimed by the manufacturer need be stated here.

(i) Because magnesium oxide has a secondary emission ratio much higher than that of glass, sensitivity is considerably enhanced - especially at low light levels.

(ii) Because of the improved stability of magnesium oxide, the tube shows stable and uniform sensitivity over a very long period, with greater freedom from raster burn.

(iii) Because the conduction mechanism of the target is electronic, instead of ionic as with the glass target, the tube does not "stick".

(iv) Because the magnesium-oxide target favours, by a high ratio, conduction through the target rather than in a direction parallel to its surface, the resolution of the tube is better than that of a conventional type.

An opportunity to assess the performance of the new target material was provided by the manufacturers when they loaned two tubes to the BBC for a short period. These tubes were available at Kingswood Warren for a little over a week, during which time one of them (type ZL 7802) was subjected to a thorough examination. The other tube (type GL 7629) was not tested, partly because of shortage of time, but mainly because it was not fitted with a field mesh and produced a rather poor quality picture in consequence. Because of the short test period no attempt could be made to evaluate any long term effects such as raster "burn-in" or permanent "sticking" or the

long term stability of those parameters which were measured. The spacing between target and target mesh in the magnesium-oxide tubes is unusually wide, i.e. 0·012 in (0·305 mm) and since it soon became apparent that the new material showed no marked difference from normal performance, it was necessary to arrange a comparison with a glass-target image orthicon having similar spacing. Accordingly, a suitable tube was obtained on loan from the English Electric Valve Company Limited of Chelmsford. This employed a conventional glass target but in other respects was identical to the American tube except for a small difference in the wide target-to-mesh spacing (0·01 in against 0·012 in, or 0·254 mm against 0·305 mm).

It is emphasized that the purpose of the comparison was to examine the relative performances of magnesium oxide and glass as target materials and that the 3 in image orthicon, was merely a suitable vehicle for the tests involved.

2. MEASUREMENTS AND RESULTS

2.1. General

Each tube was tested with a number of different levels of illumination, the following aspects of performance being measured:

(i) light transfer characteristic

(ii) resolution

(iii) signal-to-noise ratio.

In accordance with the general guiding principle that all camera-tube tests should be carried out under operating conditions as near to reality as possible, the camera was presented with an illuminated background scene, in which the test object occupied a small central area. Most camera tubes have a preferred operating point, or white level illumination, to give optimum performance. In practice, this is frequently a compromise between a number of conflicting factors such as sensitivity, available scene illumination, grey-scale portrayal and signal-to-noise ratio, but there is usually a value which is fixed for operational purposes. This same value thus determines the correct illumination for the white level of the background scene to be used when carrying out laboratory performance tests of a tube. The "wide spaced" image orthicon, however, is somewhat exceptional since it will operate consistently over a considerable range of light levels and, were it to be used in a studio, a low value of illumination would be chosen almost exclusively on the basis of reasonable lighting economy. At still lower levels the performance deteriorates, and there is a particular minimum white level below which the picture quality is unacceptable. In the case of the tubes concerned, this minimum value was determined subjectively by the mutual agreement of a number of technical observers, and defined as being that illumination which might be used to provide a broadcast television signal in circumstances of exceptional programme value. The white level illumination, so determined, was 0·006 ft-candles (0·065 lux) incident upon the photocathode. This result was obtained for both tubes and while it agrees closely with the figure claimed by the manufacturer of the tube with the magnesium-oxide target, it also shows that similar sensitivity can be achieved using a conventional glass target.

All the various measurements were carried out using three different levels of background illumination, with the lowest level determined as above. The results will be given for two levels only, however, to avoid unnecessary complication.

2.2. Light Transfer Characteristic

With the background scene illumination adjusted to the value required, the brightness of a small central area of the field was varied by the use of neutral density filters and the corresponding signal levels were recorded and plotted in the usual manner.

Fig. 1 shows the light transfer characteristics of the two tubes when operated at the minimum highlight value. It will be seen that both curves exhibit a rather high point-gamma in the darker tones although to somewhat different degrees. Fig. 2 shows the light transfer characteristics of the tubes when operated at a level of illumination which is regarded as about normal for the 3 in tube and is ten times greater than the determined minimum value. Here it will be seen that the two tubes behave almost identically over part of the characteristic but there is still a difference in point gamma in the darker tones. It is of interest to note, however, that the position is the reverse of that seen in Fig. 1, but the reasons for this are not known.

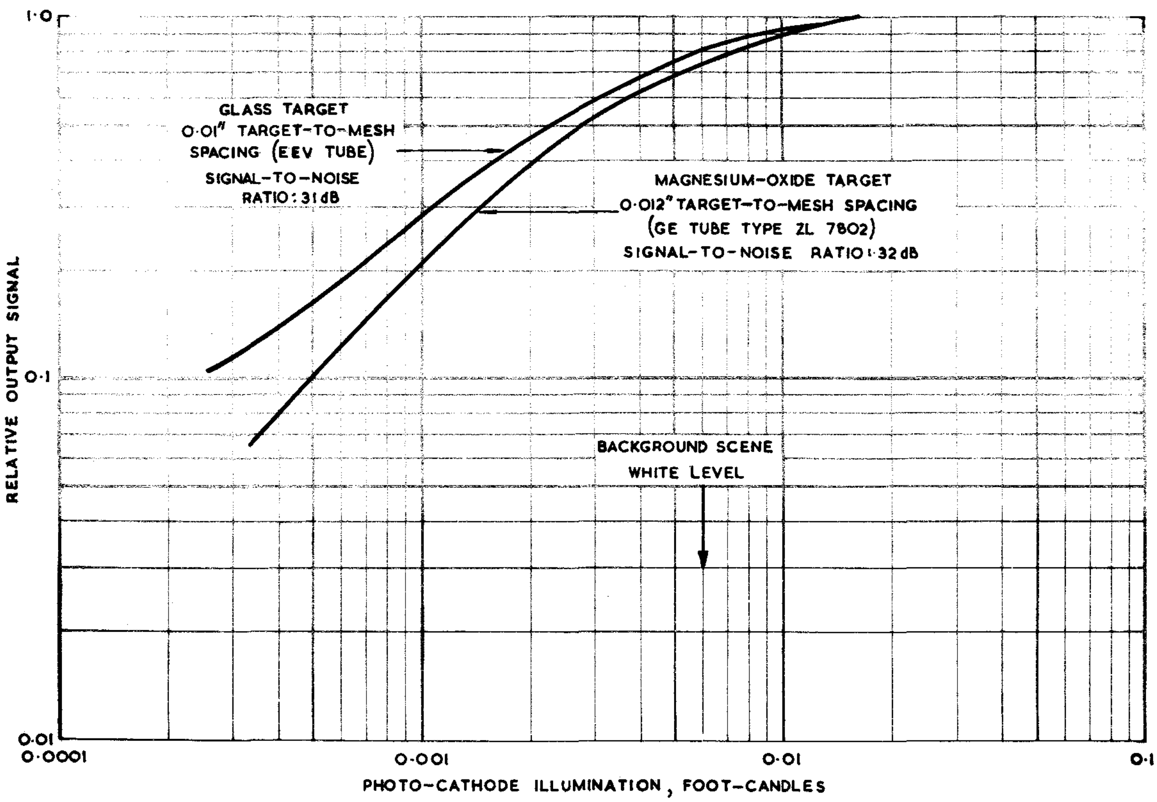

Fig. 1 - Light transfer characteristics of "wide spaced", 3 in Image Orthicon with magnesium-oxide and glass targets, at "minimum" illumination

Figs. 3, 4, 5 and 6 are photographs of the output picture from each tube under the two conditions of illumination just described. It will be seen that there is little to choose between the tubes, except that the resolution of the magnesium-oxide target to be seen in Fig. 4 is somewhat the better, as discussed later in Section 2.3. The use of contrast law correction would improve the grey-scale reproduction at low light levels, but the signal-to-noise ratio would then be unacceptably low. It should be noted that these photographs were obtained using an exposure time sufficiently long to integrate a large number of television fields and this has had the effect of concealing the rather poor signal-to-noise ratio.

2.3. Resolution

In measuring the resolution of each tube, the light level for the resolution test object was set to be 67% of the background scene highlight value in each case.

Because of the influence of "edge-effect" which gives rise to a somewhat spurious improvement in picture sharpness,[3] it is difficult to measure the intrinsic resolution of an image orthicon. The difficulty is of particular importance here, because the investigation was primarily concerned with the resolution afforded by the target material regardless of the type of tube or the magnitude of the edge-effect. Two approaches to the problem were adopted simultaneously; neither was completely satisfactory, but it is believed that reasonably accurate results were obtained.

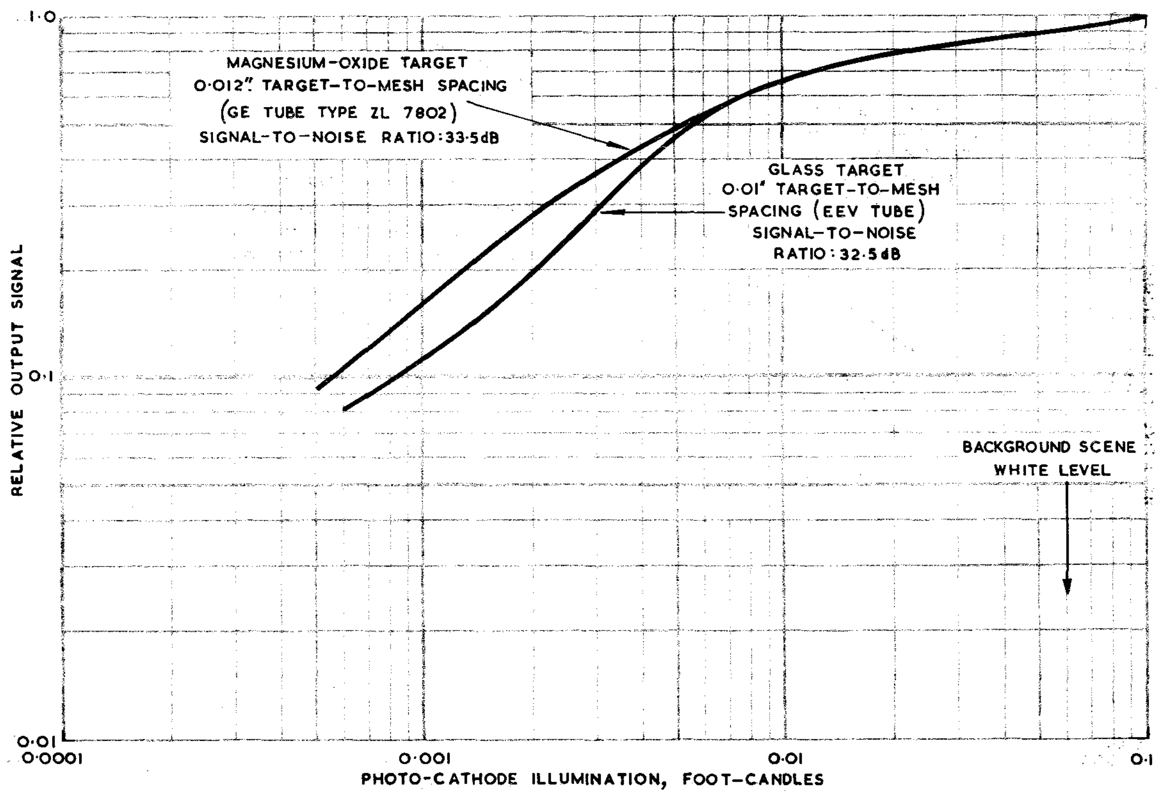

Fig. 2 - Light transfer characteristics of "wide spaced", 3 in Image Orthicon with magnesium-oxide and glass targets, at "normal" illumination

Fig. 3 - Three inch Image Orthicon with magnesium-oxide target (GE ZL 7802) and 0·012 in (0·305 mm) target-to-mesh spacing

Highlight illumination upon photocathode 0·006 ft-candles

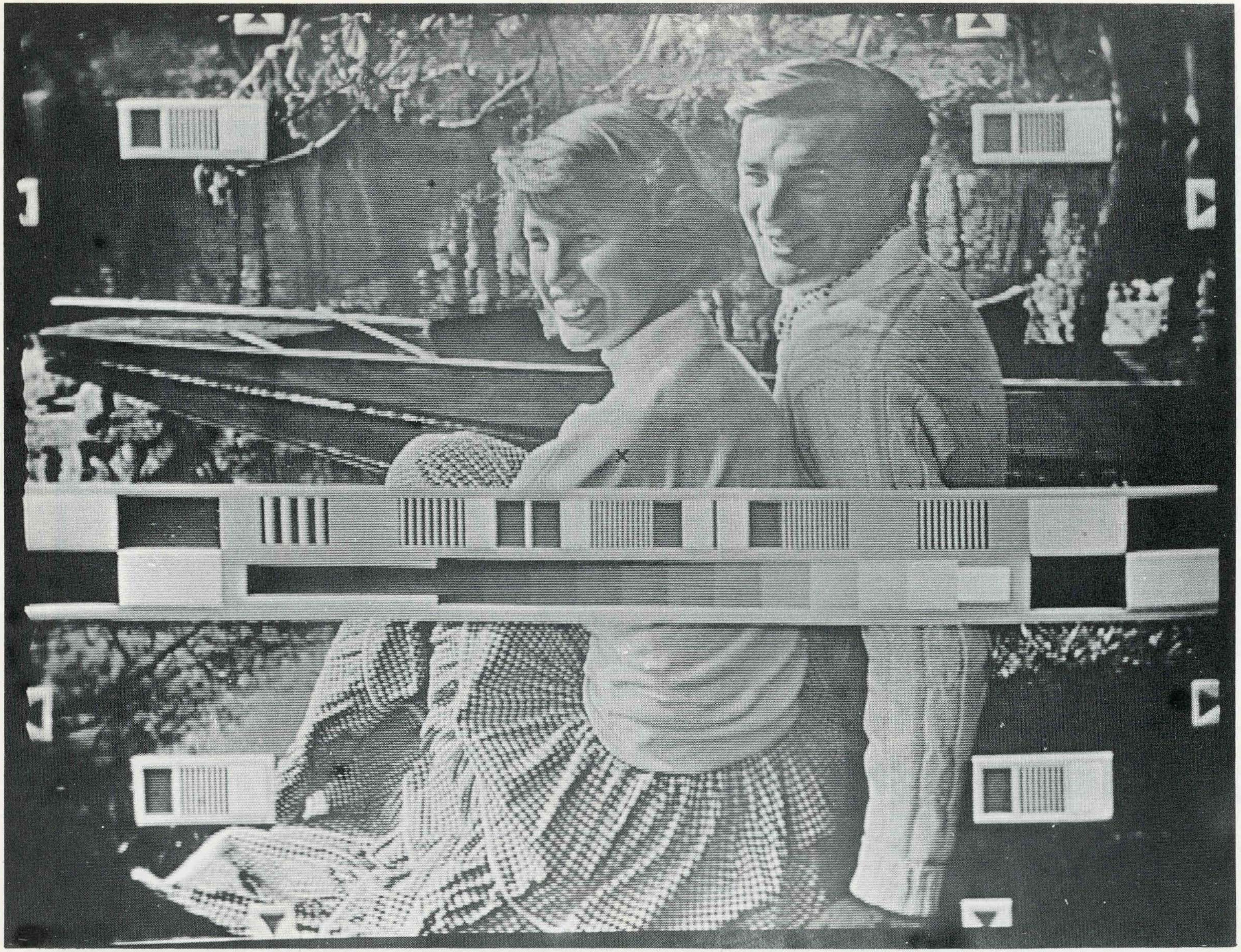

Fig. 4 - Three inch Image Orthicon with magnesium-oxide target (GE ZL 7802) and 0·012 in (0·305 mm) target-to-mesh spacing

Highlight illumination upon photocathode 0·06 ft-candles

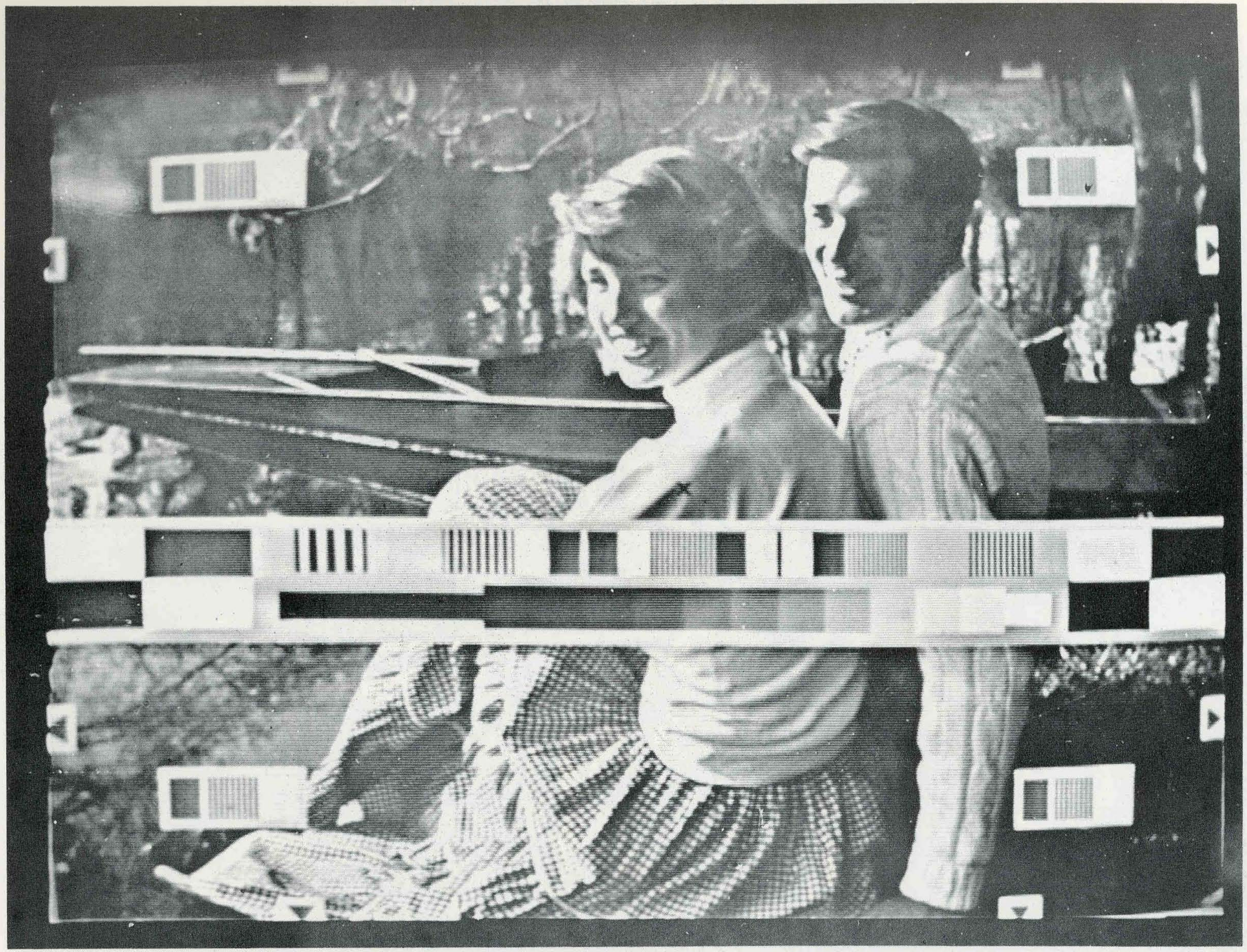

Fig. 5 - Three inch Image Orthicon with glass target (EEV) and 0·01 in (0·254 mm) target-to-mesh spacing

Highlight illumination upon photocathode 0·006 ft-candles

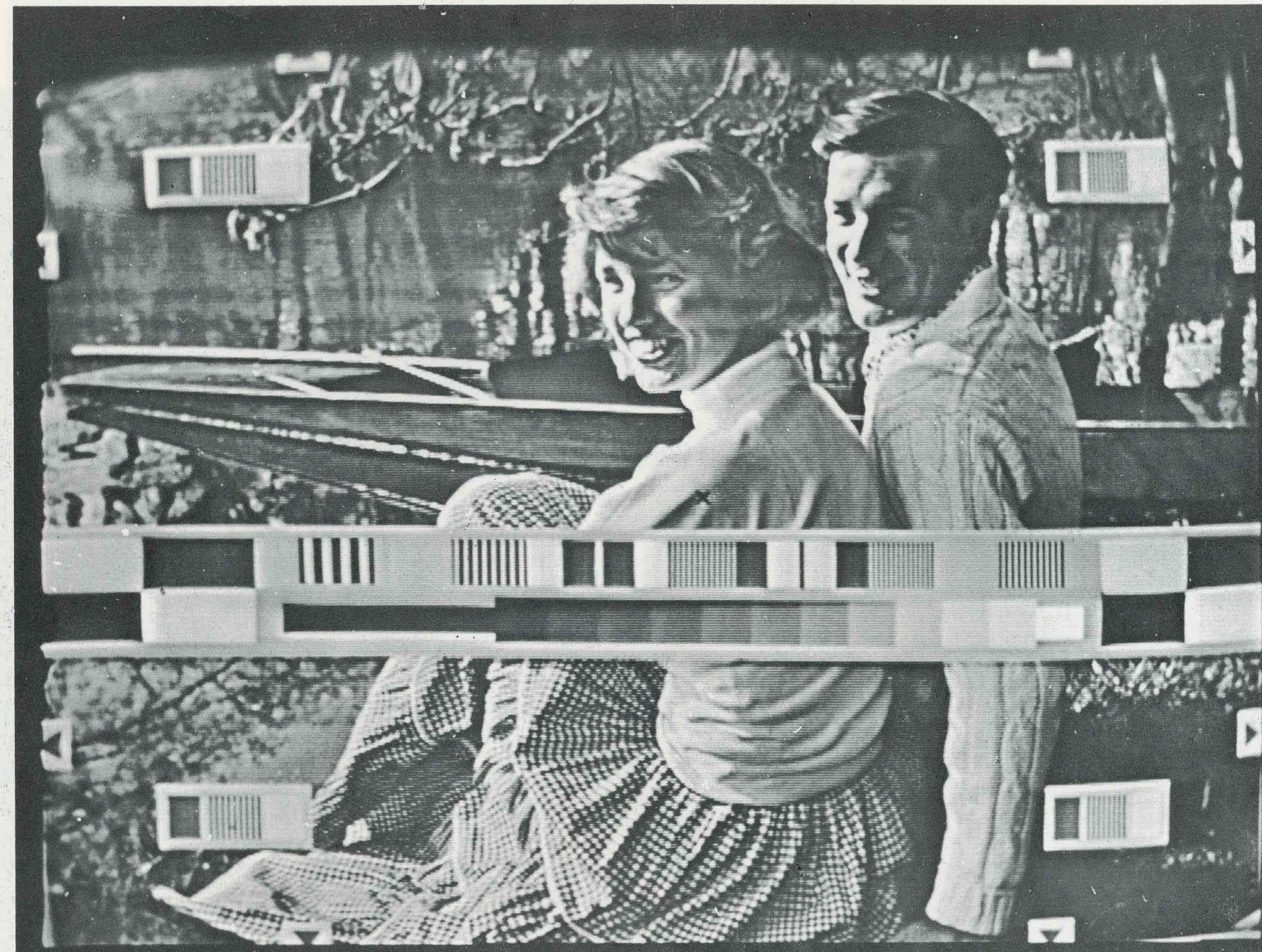

Fig. 6 - Three inch Image Orthicon with glass target (EEV) and 0·01 in (0·254 mm) target-to-mesh spacing

Highlight illumination upon photocathode 0·06 ft-candles

First, the resolution was measured at very low light levels. This precludes the influence of edge-effect and the resolution of the tube is dependent solely upon the combined electron-optical apertures of the image-section and the scanning beam, together with the absence of lateral leakage at the target. Since the two tubes were different only as regards the target, any evidence of higher resolution would be indicative of a superior target material. Unfortunately, the signal-to-noise ratios were sufficiently low to render accurate measurement very difficult and this tended to mask any difference between the tubes.

Secondly, it was possible to measure the amplitude of the edge-effect using a line-selecting oscilloscope and to allow for it when using higher levels of illumination. This method also became difficult to apply as the test patterns became finer and it was found necessary to make subjective judgements and hence to incur increasing errors. As far as was possible, however, both tubes were treated in the same way and the results may be compared, one with another, with reasonable reliability.

Fig. 7 shows the modulation transfer characteristics of the two tubes taken at two light levels. The increased resolution of the finer detail by the tube with the magnesium-oxide target is to be noted. This can also be seen in the corresponding photograph (Fig. 4) and it is believed to be due to the reduced lateral leakage obtained with this target. The resolution at low light levels, however, is seen to be the same for both tubes, possibly due to the overriding influence of poor beam landing at low target voltages, as well as the masking effect of noise upon the measurements.

2.4. Signal-to-Noise Ratio

Because of the wide spacing between the target and its associated mesh and the consequent low capacitance, the maximum value of charge carried by the target in these tubes is very much less than in conventional image orthicons. This is reflected in the very low signal-to-noise ratios which are obtained. As was expected, the magnesium-oxide target behaved similarly to glass in this respect and the values obtained are given in Fig. 1 and Fig. 2.

2.5. Sticking

"Sticking" or image-retention is a well-known and serious performance limitation of the conventional image orthicon and is found to occur after the prolonged exposure of the camera tube to an unchanging scene. It usually takes the form of a negative after-image which becomes visible when the camera is moved in relation to the scene. There are a number of different causes and effects, but three main types predominate and these are described in the Appendix.

As far as could be ascertained, the claims of the manufacturer that the magnesium-oxide target does not "stick" are fully justified. Should it become possible to fit such a target to a 4½ in image orthicon, with a much closer spacing between the target and its mesh, then the freedom from "sticking" would represent a major improvement. It is believed, however, that such a suggestion is impractical on

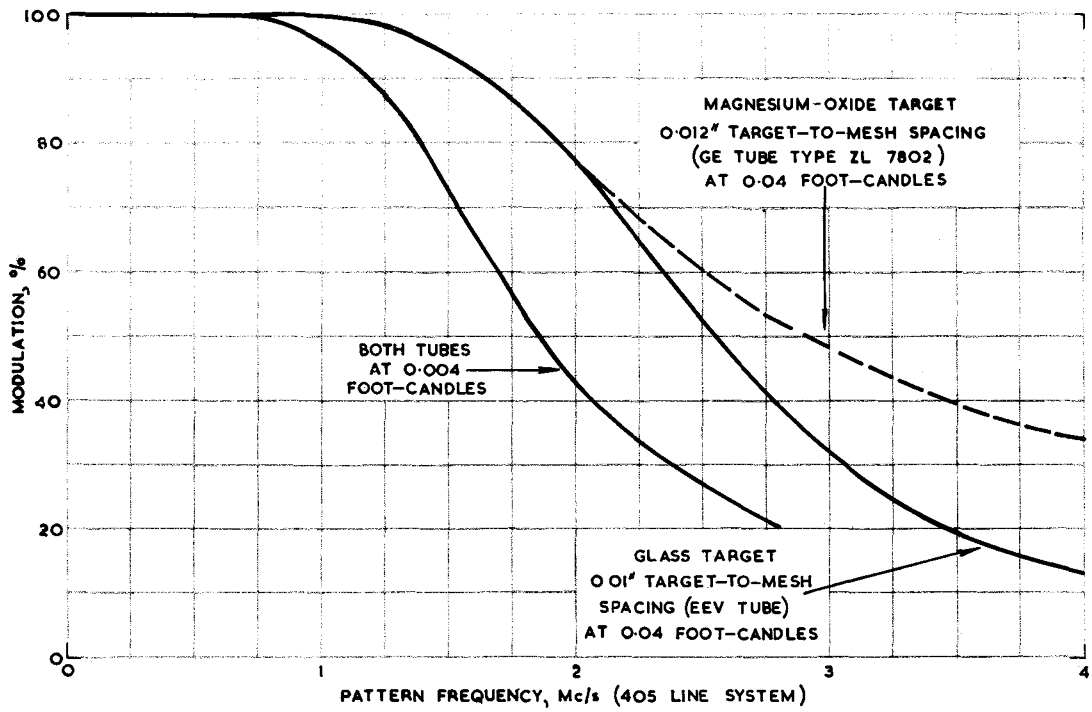

Fig. 7 - Resolution characteristics of "minimum" and "normal" illumination

account of the extreme thinness of the magnesium-oxide target and the mechanical and electrical instability which would result. It is to be hoped, therefore, that further improvements in other target materials will be made in the near future.

2.6. Target Blemishes

The tube with the magnesium-oxide target was found to have a sufficient number of spots and irregular markings upon the target to warrant its certain rejection during a routine BBC acceptance test. Since this tube was supplied for demonstration purposes, it seems likely that it was representative of the best that can be achieved at present and that this indicates a considerable need for improvement.

3. CONCLUSIONS

It has been found that a 3 in image orthicon employing a target of magnesium oxide has no greater sensitivity than a similar tube employing a glass target. It has, however, been found that the resolution of a magnesium-oxide target shows some improvement over a glass target, particularly where very fine detail is concerned. The unique freedom from "sticking" possessed by the magnesium-oxide target would be a very valuable feature if it could be incorporated without detriment into a closer spaced tube, similar to the P822 4½ in image orthicon.

4. REFERENCES

1. Iler, C.W., "Recent Advances in Camera Tube Design", International Television Symposium, Montreux 1961.

2. "A Note on Image Orthicons with Magnesium-Oxide Targets", Research Department Technical Memorandum No. T-1040.

3. "Image Orthicon Investigations: The Local Effect of Small Area Highlights", Research Department Report No. T-100/2, Serial No. 1963/4.

4. James, R.B., Johnson, R.E., and Moore, R.S., "Development and Performance of Television Camera Tubes", R.C.A. Review, Vol. X, No. 2, June 1949.

APPENDIX

"Sticking" in the Image Orthicon

Three types of "sticking" predominate in the conventional image orthicon.

(i) Temporary sticking shows as a negative after-image which quickly fades. The effect is associated with low target temperatures, when the availability of charge carriers (positive ions) is limited by temperature, and neutralization of the transverse target charge cannot be effected within the time interval between scans. The same effect will also give rise to a progressive reduction in signal amplitude when the camera is viewing the original stationary scene. The availability of charge carriers (or conductivity) increases with increasing temperature, so reducing the tendency to "stick" until a broad working optimum is reached. Beyond this, the resolution of the tube will be impaired by excessive lateral conduction.

(ii) "Burn-in" is a form of image retention in which the remains of a previous image are permanent and cannot be removed, except occasionally by further prolonged exposure to a uniform optical field. The explanation of the phenomenon depends upon the fact that the conduction of charge through the target is by means of positive ions and is irreversible, resulting in a gradual change in the contact potential of the scanned target surface during the life of the tube. The change in potential can amount to several volts[4] and can be seen in practice as a darkening of the scanned area by comparison with the white border obtained when temporarily over-scanning. Permanent sticking or "burn-in" is thus caused by a contact potential "image" resulting from local ageing of the target during prolonged exposure.

(iii) Sticking due to long service is intimately related to the two effects just described and occurs only in tubes which have been in use for a long period. In character it is similar to temporary sticking described earlier, but in this case the effect occurs at the normal operating temperature of the tube. Its onset is due to the near exhaustion of the supply of charge carriers in the target glass, which results in a decreasing value of conductivity. The circumstances are thus similar to those obtaining in a cold but otherwise normal tube when temporary sticking occurs. Some manufacturers and broadcasting authorities regard the onset of this form of sticking as the criterion for the ultimate rejection of the tube, or the end of its useful life, but in BBC studios it is found that the failure of some other parameter usually occurs first.

The effects of sticking can be concealed from the viewer by careful operation, but the inconvenience and expense to the broadcasting authority are considerable.

The use of the image orthicon in standards conversion equipment is also influenced on this account. When the originating source employs image orthicon cameras, the standards conversion camera tube will automatically receive protection from sticking. This protection disappears, however, when a still picture or test pattern is transmitted and permanent sticking or "burn-in" is a common and objectionable occurrence due to this cause.

ALG

Printed by B.B.C. Research Department, Kingswood Warren, Tadworth, Surrey